CHAPTER 1

INTRODUCTION

The Office of Energy Efficiency and Renewable Energy (EERE) develops—and encourages consumers and business to adopt—technologies that improve energy efficiency and increase the use of renewable energy. This report describes analysis undertaken by EERE to better understand the extent to which the technologies and market improvements funded by its FY 2004 Budget Request[1] will make energy more affordable, cleaner, and more reliable.

The Government Performance and Results Act (GPRA) of 1993 requires Federal Government agencies to prepare strategic plans, annual performance plans, and annual performance reports. This EERE benefits analysis supports these GPRA requirements by developing an assessment of the benefits that may accrue to the Nation if the performance goals of EERE's programs are realized. The consumer energy-cost savings,[2] carbon emission savings, and reduced reliance on fossil fuels estimated here result from the increased use of energy-efficient technologies and increased production of renewable energy resources, which are supported by the technology advances and market adoption activities pursued by EERE programs.

EERE initiated its benefits analysis in 1994. Through the 1990s, EERE program offices continued to refine their benefits-analysis methodologies and assumptions, and an annual external review of the methodologies and assumptions employed was initiated in 1997 and continued through 2001 when EE was reorganized. Although the benefits analysis has changed since it was initiated 10 years ago, the energy saved or displaced continues to be the key measure of the EERE program impact.

With its reorganization in 2002, EERE centralized the benefits-analysis effort within the Office of Planning, Budget Formulation, and Analysis (PBFA) and integrated it into the broader planning and analytical needs of EERE. While technology information (such as cost and performance) is still provided by the EERE programs, market analysis is now conducted by PBFA.

The analysis summarized in this report is based on the technological and deployment impacts of the EERE program activities, with the following key assumptions:

- Programs will be funded at the levels requested in DOE's fiscal year (FY) 2004 Budget Request;
- Funding levels will remain constant in inflation-adjusted dollars or rise to accommodate key initiatives in particular cases, as indicated;

[1] See http://www.eere.energy.gov/office_eere/budget.html.

[2] These consumer cost savings are the gross savings from avoiding purchased energy. They are not net of the investments that would have to be undertaken to achieve these savings. The NEMS model does not currently address net costs, and these are considered separately.

- Programs will achieve their technology and market targets and goals based on the assumption that one of the many technical paths pursued will succeed. It is important to note that this assumption of technical success, although uncertain, is generally not dependent on a single technical pathway and instead encompasses a number of alternative approaches, of which many may fall short without jeopardizing realization of the final goal. For most programs, the basic technical capability for achieving the overall goal is already demonstrated. For example, the efficiency of thin-film photovoltaic cells needed to achieve the overall PV program goal already has been demonstrated in the laboratory, and no additional breakthroughs are needed. Further, there are several completely different PV materials and manufacturing processes by which the goal could be realized. For some technologies, significant technical advances are still needed.

The analysis is budget-based. As such, it addresses the performance-budget integration goal of the President's Management Agenda (PMA). It also addresses the benefits criterion in the R&D Investment Criteria developed by the Office of Management and Budget (OMB) as part of the PMA.

Role of Benefits Analysis in Performance Management

EERE employs a widely used logic model as the foundation for managing its portfolio of efficiency and renewable investments[3] and for ensuring that these investments provide energy benefits to the Nation. In its simplest form, this logic model identifies budget and other *inputs* to a program, *activities* conducted by the program, and the resulting *outputs* and *outcomes* of those activities (**Figure 1.1**). The logic model provides an integrated approach that explicitly links requested budget levels to performance goals and estimated benefits—and helps ensure that estimated benefits reflect the funding levels requested. The elements of the logic model are specified in GPRA and are included in the annual budget request.

Multiyear Program Plans (MYPPs),[4] developed by each of EERE's 11 programs, address the *inputs* required, the *activities* that will be undertaken with their requested budget, the performance *milestones* they expect to achieve as they pursue these activities, and the resulting products or *outputs* of this effort.[5] Inputs may include cost-shared or leveraged funds as well as EERE program dollars—and may also include advances by others on which the program builds. Performance milestones capture intermediate points of discernable progress toward outputs and are used by program managers, DOE, OMB, and others to track program progress toward their

[3] The logic model is a fundamental program planning and evaluation tool. For more information on logic models, see: Wholey, J. S. (1987). *Evaluability assessment: developing program theory. Using Program Theory in Evaluation*. L. Bickman. San Francisco, CA, Jossey-Bass. 33. Jordan, G. B. and J. Mortensen (1997). "Measuring the performance of research and technology programs: a balanced scorecard approach." *Journal of Technology Transfer* 22(2). McLaughlin, J. A. and J. B. Jordan (1999). "Logic models: a tool for telling your program's performance story." *Evaluation and Program Planning* 22(1): 65-72.

[4] These program plans are being formalized as part of the EERE reorganization. Final plans will be available during 2004. For this transitional year, benefit analysts worked with any updated program goals available and utilized existing goal statements where necessary.

[5] See the Government Performance Results Act (GPRA) of 1993 at http://www.whitehouse.gov/omb/mgmt-gpra/gplaw2m.html and http://www.whitehouse.gov/omb/circulars/a11/02toc.html

outputs. Outputs, often referred to as "program goals" or "program performance goals,"[6] are the resulting products or achievements of an overall area of activity. EERE's R&D programs typically specify their outputs in terms of technology advances (e.g., reduced costs, improved efficiency), while deployment programs develop outputs related to their immediate market impacts (e.g., number of homes weatherized). Outputs[7] evolve over time as the program pursues increasing levels of technology performance or market penetration.

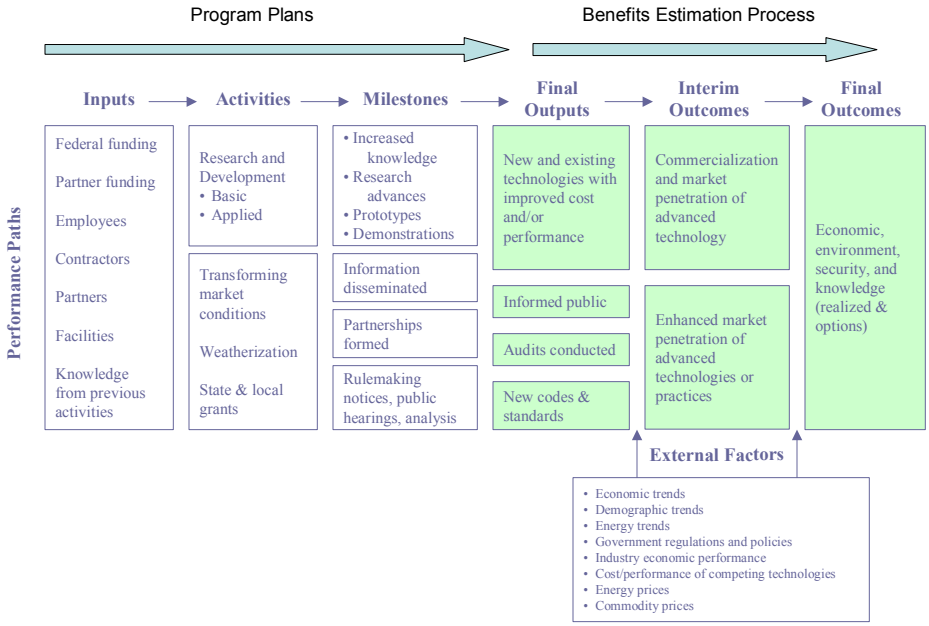

Figure 1.1. Generalized EERE Logic Model

This benefits analysis links these program outputs to their market impacts or outcomes. EERE's programs have discernable effects on energy markets, both by reducing the level of energy demand (through efficiency improvements) and by changing the mix of our energy supplies (through increased renewable and distributed energy production). EERE incorporates these two effects in its primary *outcome*—the displacement of conventional energy demand.

These changes in energy use provide the basis for the economic, environmental, and security benefits estimated here. The extent to which a new technology or a deployment effort changes energy markets will depend on a variety of external factors. The future demand for energy, its price, the development of competing technologies, and other market features (such as consumer preferences) all will contribute to the marketability and total sales of a new technology.

[6] Some programs derive their outputs through technology-cost simulation models to develop the specific requirements to meet overall program cost and performance goals. Specific details of the representation of the program outputs in NEMS-GPRA04 and the underlying program analysis and documentation are found in Chapter 4 of this report and Appendices B through E.
[7] The level of risk for the programs is assessed qualitatively as part of the Office of Management and Budget (OMB) R&D Investment Criteria. EERE is developing a standard approach to assessing technology and program risk.

Benefits Framework

The EERE Benefits Framework addresses the last three columns of the logic model: the link between program outputs with resulting outcomes and benefits. The benefits analysis is based on the specific program goals or outputs specified by EERE programs in their program plans and the EERE budget request, and on estimated future energy market conditions (external factors). EERE estimates its primary outcome—displaced conventional energy consumption—by comparing future energy consumption with and without the contributions of its program outputs. The market impacts of each of the 11 programs are assessed separately and then combined to assess the benefits of EERE's overall portfolio.

EERE, along with the Office of Fossil Energy (FE), is in the process of adopting a framework initially developed by the National Research Council (NRC) to assess the benefits associated with past EERE research efforts (see **Box 1.1, National Research Council Review**). EERE's annual estimates of prospective benefits have been incorporated into an integrated framework addressing the benefits of both existing and future program activities. The framework is represented in a matrix, in which the rows distinguish among four types of benefits and the columns represent different elements of time and uncertainty.

This report addresses the three shaded cells of the matrix, reflecting benefits under a business-as-usual energy future. EERE and FE currently are developing methods for assessing the value to the country of developing technologies that prepare the Nation for unexpected energy needs. These results will be in the "option" column in future reports.[8] Similarly, EERE is in the process of extending the NRC analysis of realized benefits to include its full portfolio (**Figure 1.2**).

	Realized Benefits and Costs	Expected Prospective Benefits and Costs	Options Benefits and Costs
Economic Benefits and Costs		X	
Environmental Benefits and Costs		X	
Security Benefits and Costs		X	
Knowledge Benefits and Costs			

Figure 1.2. FY 2004 Benefits Metrics Reported

Completing the cells of this matrix in ways that provide comparable results across programs (and DOE offices) poses a number of analytical challenges, especially in light of the varied portfolio that EERE maintains:

- **Standard baseline(s) and methodology.** EERE uses the Energy Information Administration's (EIA) reference case as a consistent starting point for analysis of all of its programs. A standard methodology is used to assess the incremental improvements to energy efficiency and renewable energy production, resultant from realization of EERE

[8] For its retrospective study, the NRC defined an option as a technology that is fully developed—but for which existing market or policy conditions are not favorable for commercialization. Because current technology choices are known, noncommercial (but developed technologies) are options, by default. A more general definition for prospective analysis—expressed in the Real Options literature—defines a real option as an asset, such as a technological innovation that creates future choices (i.e., options) and establishes an analytic decision-making framework on how to enhance asset value at future points in time. See Dixit, Avinash K., and Robert S. Pindyck, *Investment under Uncertainty*, Princeton University Press, Princeton, New Jersey (1994).

program goals. This methodology addresses approaches and assumptions that are applicable to all of EERE's program activities and markets.

- **Varied markets.** Program activities target all end-use markets (buildings, industry, transportation, and government) and energy supply markets (use of renewable energy as new sources of liquid and gaseous fuels, and electricity). Because these markets vary enormously in structure, regulation, and consumer preferences, a fairly detailed, market-specific analysis often is needed to gain sufficient understanding of the size and potential receptivity of each market to EERE's activities. EERE strives to incorporate these unique market features that are likely to have a significant impact on the resulting benefits.

- **Varied time frames.** The analytical time frame extends from a few years to the decades that are required for the development of new energy sources, infrastructure, market penetration, and product life cycle. This expansive time frame requires a baseline and analytical tools that can address energy markets in the short, mid-, and long term. This report addresses short- (5–10 years) and mid-term (10–20 years) time frames. EERE is developing tools to address the long term (20–50 years) for the FY 2005 budget cycle.

- **Numerous market feedbacks.** EERE technology and deployment efforts can have large enough effects on their respective energy markets that they generate supply or price feedbacks. EERE's products also can interact with each other across their respective energy markets. For example, efficiency improvements in end-use markets can be large enough to forestall the development of new electricity-generating plants, reducing the potential growth of wind and other renewable electricity sources. Past EERE experience indicates that failure to reflect market responses tends to overestimate benefit levels. EERE utilizes an integrated energy-economic model to produce final benefit estimates that consider these feedbacks and interactions at the program and portfolio levels.

EERE's 2002 Reorganization

EERE reorganized in June 2002. The previous organization, consisting of five sectors (buildings, federal, industry, power, and transportation) and 31 programs was replaced by a set of 11 programs. This reorganization facilitated use of the logic model, with clear program responsibilities for linking inputs to outputs. A new analysis group—Planning, Budget Formulation, and Analysis (PBFA)—assumed responsibility for assessment of outcomes and benefits related to these program outputs.

Under the prior organization, benefit analyses were undertaken by each of the five sectors for the programs within their sector, with guidance provided by EERE management. These analyses provided program-level estimates of benefits, but did not account for feedbacks from other markets—or, in some cases, even within target markets. The annual guidance provided a consistent basis for estimating benefits across programs, but the disaggregated nature of the analysis often made it difficult to implement this guidance in a consistent way. The energy savings from these individual program estimates were then assessed, using an energy-economic model to estimate the savings across EERE's entire portfolio.

The new organization brings together a team of analysts, which includes experts in both individual energy markets and energy-economic modeling. This new team enables EERE to take market feedbacks into account at the program level, as well as at the portfolio level. It also enables analysts to improve coordination in implementing EERE's benefits methodology.

The FY 2004 benefits analysis was initiated under the old organization. As a result, the program-level analyses were undertaken based on the prior sector structure. As in past years, each sector report (**Appendices B through E**) includes program-level energy savings estimates, which do not include feedback effects. With the creation of the integrated analysis team midway through this analysis effort, it was possible to produce a final set of 11 program benefit estimates that account for market feedbacks. It is these final integrated estimates that are included in this report and that appear in the EERE FY 2004 Budget Request.

Analysis Team

This report summarizes program benefits analysis undertaken by experts in energy technology programs, energy markets, and energy-economic modeling. The primary team members and their areas of responsibility are listed below.

Management and Overall Responsibility

- EERE
  - Integrated: MaryBeth Zimmerman, Susan Holte, Phil Tseng
  - Buildings: Jerry Dion
  - Industry: Ken Friedman, Peggy Podolak
  - Transport: Phil Patterson
  - Power: Tina Kaarsberg, Susan Holte
  - Bioenergy: Tien Nguyen
- Contractors
  - Project Managers: Bill Babiuch, Doug Norland (NREL)
  - Guidance: Patrick Quinlan (NREL), John Mortensen (Independent Consultant), Jim Wolf (Independent Consultant)
  - Energy-Economic Integration: Frances Wood, John Holte, Aliza Seelig (OnLocation, Inc.); Chip Friley, John Lee (BNL)

R&D and Deployment Programs

- Biomass: Jerry Hadder (ORNL); Michael Wang (ANL); Roger LeGassie, Steve Zukor (TMS); David Andress (D. Andress & Associates); Margaret Singh (ANL); David Andress, Tracy Carole (Energetics); Larry Goldstein (NREL); Tom Schweizer (PERI)
- Buildings: Dave Anderson, David Belzer, Katie Cort, Jim Dirks, Donna Hostick, Sean McDonald (PNNL)
- Distributed Energy and Electric Reliability (DEER): Larry Goldstein (NREL), Tom Schweizer (PERI)
- Federal Energy Management Program (FEMP): Daryl Brown, Andrew Nicholls (PNNL)

- FreedomCAR and Vehicle Technologies: Margaret Singh (ANL), Elyse Steiner (NREL), Jim Moore (TA Engineering, Inc.)
- Hydrogen and Fuel Cells: Margaret Singh, Steven Plotkin (ANL); Elyse Steiner (NREL)
- Geothermal: Larry Goldstein (NREL); Tom Schweizer, Dan Entingh (PERI)
- Green Power: Jim McVeigh (PERI)
- Industry: Jim Reed (Independent Consultant); Joan Pellegrino, Nancy Margolis, Shawna Mcqueen, Diane McBea (Energetics); Ken Greene, Bill Choate, Roy Tiley (BCS); John Mortensen (Independent Consultant); Douglas Norland (NREL); Peter Angelini (ORNL); Elmer Fleischman (INEL)
- Inventions and Innovations: Nancy Moore (PNNL)
- Renewables (all): Chris Marnay, Kristina Hamachi LaCommare (LBNL)
- Solar: Larry Goldstein (NREL), Tom Schweizer (PERI)
- Wind and Hydropower: Larry Goldstein (NREL), Tom Schweizer (PERI)
- Weatherization and Intergovernmental Programs (WIP): David Anderson, David Belzer, Katie Cort, Jim Dirks, Donna Hostick, Duane Deonigi, Nancy Moore (PNNL)

In all cases, these lead analysts drew on the studies and expertise of many others. Much of this supporting work can be found in the references provided here and in the appendices.

Report Organization

This report is organized into three additional chapters. **Chapter 2** describes the process and methodology employed by EERE to estimate program and portfolio economic, environmental, and security benefits from its RD&D programs. **Chapter 3** presents the overall results of the savings estimates from the individual programs and from a total EERE portfolio perspective. **Chapter 4** describes, in detail, the results of each program area.

Five appendices are included. **Appendix A** provides the Baseline and Portfolio Cases. **Appendices B through E**, respectively, provide sector-analysis team inputs for buildings, industry, renewables, and vehicles.

Box 1.1—National Research Council Review

Energy Research at DOE: Was It Worth It?

In 1999, at the request of the U.S. Congress, the National Research Council (NRC) of the National Academy of Sciences began a retrospective study of the benefits of EERE energy efficiency RD&D programs, examining activities from 1978 to 2000. The activities examined accounted for about one-fifth of the cumulative EERE funding for energy efficiency projects, excluding renewable technology programs. Using a conservative methodology to evaluate about $1.6 billion of the EERE energy efficiency programs, the NRC found a net realized economic benefit of approximately $30 billion, or a return of about $20 for each $1 of EERE investment in the programs considered.* Also included in the study were the R&D programs of DOE's Office of Fossil Energy.

The methodological framework developed by the NRC was designed to reflect the public policy purpose of the R&D and the state of commercialization of the R&D activity. A matrix was developed to represent these features, as shown in the table below. The rows of the matrix represent the net benefits to be achieved by the R&D (accounting for any extra costs as well as benefits associated with the new technology). After reviewing energy policy documents, the committee concluded that the benefits of energy R&D can be grouped into three primary categories: economic benefits, environmental benefits, and security benefits (including reliability).

The columns of the matrix represent the state of the R&D activity and related technologies at the time of the evaluation. Realized benefits are those achieved by technologies that have been successfully developed or are in final development and demonstration, for which current economic and policy conditions are favorable for deployment in the marketplace. Options benefits are for technologies that are under development or are technologically successful, for which economic or policy conditions are not yet favorable to their deployment but could become favorable under reasonable future scenarios. Knowledge benefits are for those technologies for which R&D is not yet completed, for technologies that would not be commercialized, and for technologies for which development was unsuccessful but nevertheless yielded knowledge that is potentially applicable elsewhere. The NRC study did not evaluate knowledge benefits for successful technologies.

	Realized Benefits and Costs	Options Benefits and Costs	Knowledge Benefits and Costs
Economic Benefits and Costs			
Environmental Benefits and Costs			
Security Benefits and Costs			

DOE's offices of Energy Efficiency and Renewable Energy, Fossil Energy, Nuclear Energy, and Science cosponsored DOE's "Estimating the Benefits of Government-Sponsored Energy R&D"** (March 2002) to explore ways of extending this framework to include the prospective benefits of program activities. As a result of the conference, the matrix was revised by placing knowledge as a benefit and explicitly showing expected prospective benefits and costs in addition to realized benefits and costs.

* The estimated benefits were based on analyses of 17 case studies. The estimated benefits also assumed that without the EERE program, the technology would have been developed and introduced in the market five years later by the private sector. In addition, the NRC stopped counting benefits for technology units entering the market after 2005.
** See www.esd.ornl.gov/benefits_conference.